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Association between Dietary Patterns and Serum Adiponectin: A Cross-Sectional Study in a Japanese Population

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Association between Dietary Patterns and Serum Adiponectin: A Cross-Sectional Study in a Japanese Population

The aim of this study was to evaluate the associations between dietary pattern, adiponectin, and insulin resistance. The study population consisted of 612 men and women aged 35-69 years old who had participated in the baseline survey of Japan Multi-Institutional Collaborative Cohort (J-MICC) Study in Tokushima Prefecture. Diets and lifestyle related variables were assessed by questionnaires. Multiple regression analyses were used to analyse the relations between dietary patterns and high molecular weight adiponectin. For further analysis, path analysis was used to test the hypothesized model of association between dietary pattern, serum adiponectin, and insulin resistance. The result showed that higher score of bread and dairy pattern was directly associated with increased serum level of adiponectin in women, which was inversely related to Homeostasis Model Assessment of Insulin Resistance. In conclusion, higher consumption of bread and dairy products, and low intake of rice may be associated with increased serum adiponectin in women.

Keywords: adiponectin, dairy, dietary pattern, insulin resistance, path analysis

Introduction

Metabolic syndrome can be defined as a cluster of risk factors, such as abdominal obesity, hypertension, dyslipidaemia, and glucose intolerance (Balkau & Charles 1999; Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol In Adults 2001). The number of people who suffer from this condition is increasing worldwide (Cameron et al. 2004). Most people who suffer from metabolic syndrome have insulin resistance (Grundy et al. 2004) and are at increased risk of type II diabetes and cardiovascular diseases (Alberti et al. 2009). To measure the insulin resistance in large population-based epidemiological investigations, the usage of surrogate assessment of insulin resistance named Homeostasis Model Assessment of Insulin Resistance (HOMA-IR), has been proven to be an effective tool (Antuna-Puente et al. 2011).

Adiponectin is a glycosylated adipokine selectively secreted from adipocytes and its function is related to glucose uptake, beta-oxidation, regulation of insulin, and play a role in the regulation of inflammation (Xu et al. 2007; Mittal 2008). Lower concentrations of plasma adiponectin are associated with decreased insulin sensitivity, whereas individuals with high concentrations of serum adiponectin were less frequent to develop type II diabetes (Lindsay et al. 2002) and cardiovascular disease (Pischon et al. 2004).

In human blood, adiponectin circulates in different isoforms: high molecular weight (HMW), middle molecular weight (MMW), and low molecular weight (LMW) (Pajvani et al. 2003; Waki et al. 2003). Compared with plasma total adiponectin, HMW adiponectin is more useful for predicting insulin resistance and metabolic syndrome (Hara et al. 2006).

From the standpoint of preventing metabolic syndrome, type 2 diabetes and cardiovascular diseases, understanding the factors that favourably modify serum adiponectin concentrations would be an important priority. Even though a previous study from Japan suggested that none of the nutrient intakes had significant association with serum adiponectin concentration, (Murakami et al. 2013) another study has shown the significant relation between Japanese traditional dietary pattern and serum adiponectin (Guo et al. 2012). Meanwhile, studies from the U.S. showed significant associations between adherence to Mediterranean dietary pattern (Mantzoros et al. 2006) or healthy eating pattern (Fargnoli et al. 2008) and adiponectin.

In this study, we tried to investigate the association between major dietary pattern and HMW adiponectin. Furthermore, we analysed the association between dietary pattern, serum adiponectin, and insulin resistance by using path analysis.

Materials and methods

Study population

The population for the present study consisted of 697 participants aged 35 to 69 years old, who were enrolled in the baseline survey of the Japan Multi-Institutional Collaborative Cohort (J-MICC) Study in Tokushima Prefecture, Japan. Details about J-MICC Study have been described in the previous report (Hamajima 2007). In short, the aim of the J-MICC Study was to examine the prospective associations of lifestyle and genetic factors and their interactions with the risk of lifestyle-related diseases. We distributed approximately 98,700 leaflets explaining the objective and method of the J-MICC Study in all over Tokushima city, with a total population of 264,500. Within July

25th 2012 to February 27th 2013, there were 697 subjects who read the leaflets and attended the health check-ups performed by our research team. Written inform consent was obtained from participants after we explained about the outline and the objectives of this study. The participation rate was difficult to calculate because of the recruitment method. The study protocol was approved by the review boards of Nagoya University School of Medicine (an affiliate of the former principal investigator, Dr. Nobuyuki Hamajima), Aichi Cancer Center Research Institute (affiliated with the present principal investigator, Dr. Hideo Tanaka), and Tokushima University Hospital.

We excluded participants who had history of ischemic heart disease (n = 21), stroke (n = 9), or diabetes mellitus (n = 28), or who received medical treatment with anti-diabetic drugs (n = 22). Participants might be excluded for one or more reasons. Subjects with missing values of serum adiponectin (n = 9) and other variables (n = 24) were also excluded from the study. These exclusions gave final study population of 612 participants (437 women and 175 men) for statistical analysis.

Questionnaire

In this study, subjects were asked to fill out the self-administered questionnaire about dietary habits, current and previous diseases, medication and supplements consumption, physical activity, and smoking and drinking habits. Questionnaires were sent to participants approximately 2 weeks before the health check-up. Validated short food frequency questionnaire (FFQ) was used for dietary evaluations (Tokudome et al. 2004; Tokudome et al. 2005; Goto et al. 2006; Imaeda et al. 2007). Dietary intake information was collected by asking the participants about how often they consumed 46 foods and 9 beverages over the past year. Consumption of rice, bread, and noodle at breakfast, lunch and dinner were divided into six categories: rarely, 1-3 times per month, 1-2 times per week, 3-4 times per week, 5-6 times per week, and every day. Other foods intake including coffee and green tea, was categorized into 8 categories: rarely, 1-3 times per month, 1-2 times per week, 3-4 times per week, 5-6 times per week, once per day, 2 times per day, and ≥3 times per day. Beverages consumption was divided into seven categories: rarely, less than 2 cups per week, 3-4 cups per week, 5-6 cups per week, 1-2 cups per day, 3-4 cups per day, ≥5 cups per day. Information on the portion size was collected only for staple foods. Average daily consumption of energy and selected nutrients were computed using a program developed by Department of Public Health, School of Medicine, Nagoya City University (Tokudome et al. 2004; Tokudome et al. 2005). A relative validation study was completed by comparing the intake of energy and 26 nutrients evaluated using this FFQ and 3 day-weighed diet records (3d-WDRs) as a reference. Deattenuated, log-transformed, and energy-adjusted Pearson's correlation coefficients for 26 nutrients intake distributed from 0.10-0.86 (Tokudome et al. 2005). This FFQ had substantially high one-year interval reproducibility values for consumption of foods and nutrients assessment (Imaeda et al. 2007).

Smoking status was self-reported and classified into current smoker, past smoker, and never, whilst drinking habit was categorized into 3 groups, current drinker, past drinker, and never. Physical activity during leisure time was estimated by multiplying the frequency and the average duration of light exercise (such as walking and golf are 3.4 metabolic equivalents [METs]), moderate exercise (such as jogging, swimming and dance are 7.0 METs), and vigorous-intensity exercise (such as marathon is 10.0 METs). The three levels of exercise were summed to obtain the MET-hours/week.

Anthropometric and biochemical measurement

Data on anthropometric measurement (height, weight, and waist circumference), fasting plasma glucose, and insulin were obtained at the time when participants came for the health check-up performed by our research team. Participants were requested not to eat breakfast and received medical check-up between 8.00 AM to 11.00 AM. Venous blood samples were collected from all participants and serum was separated within 3 hours. HMW adiponectin levels were assessed by the external laboratory using latex turbidimetric immunoassay (SRL, Tokyo, Japan). Serum insulin was measured using a chemiluminescence immunoassay (BML Inc., Tokyo, Japan).

Homeostatic Model Assessment (HOMA) is a method for assessing β-cell function and insulin resistance from basal (fasting) glucose and insulin or C-peptide concentrations. The equation used to calculate HOMA-IR was insulin (μU/mL) x plasma glucose (mg/dL)/405 (Matthews et al. 1985).

Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2).

Statistical Analysis

To extract the dietary pattern, we used principal component analysis (PCA) by PRINCOMP procedure from SAS software package (version 9.4). The components of dietary patterns obtained from PCA reflect the combinations of foods consumed by each participant. In determining the number of dietary patterns to be retained, we considered the eigenvalues (≥1.0), scree test, and interpretability. Retained dietary patterns were named based on the highest factor loadings on each pattern. We analysed the relation between retained dietary pattern scores and serum adiponectin in men and women separately, by using multiple regression analysis adjusted for potential confounders. Model 1 adjusted for age. Model 2 included all variables from model 1 and additionally adjusted for energy intake, physical activity, drinking habit, smoking habit, and menopausal status (in women only). Model 3 included all variables from model 2 and further adjusted for BMI. Hypothetical path diagram was constructed based on the result of multiple regression analysis and the results of prior studies.

To examine the baseline characteristics, continuous variables are shown as median (25^{th} and 75^{th} percentiles) and categorical variables are presented as the count and proportion. The differences across the quartiles of dietary pattern scores were examined using the Chi-square test, Kruskal-Wallis test, or Fisher's exact test.

The hypothetical path diagrams were analysed using path analysis, performed by IBM® SPSS® AMOS™ (Version 22). Path analysis is an analysis involving assumptions about the direction of causal relationships between linked sequences and configuration of variables (Porta 2008). Listwise deletion method was used to handle the missing data. The covariates included in the path analysis were the available predictors of adiponectin, dietary pattern, and BMI: age, energy intake, physical activity, drinking habit, smoking habit, and menopausal status. The assessment of model fit was performed using the following parameters: chi-square test (χ^2), RMSEA (Root Mean Square Error of Approximation), CFI (Comparative Fit Index), and NFI (Normed-Fit Index).

Chi-square is a traditional measure for estimating the overall model fit and evaluate the discrepancy between the sample covariance matrix and the fitted covariance matrix (Hu & Bentler 1999). The insignificant result at 0.05 threshold is necessary for good model fit (Barrett 2007). Nevertheless, χ^2 is sensitive to sample size. As a result, χ^2 nearly always rejects the model when the sample size is large. Therefore, it is necessary to use the incremental fit indices as well (Choi et al. 2014). Incremental fit indices show the relative improvement of hypothesized model compared to the null model – typically no correlation among observed variables was assumed (Kline 2011).

Results

Five dietary patterns were extracted by PCA. These patterns accounted for 34.09% of the total variance of food intakes. There were 9 other factors showing eigenvalue ≥1.0, but the interpretation of those components was difficult. The scree plot (see supplementary figure 1) suggested five factors to be retained. Table 1 shows the factor loadings of each food item in the extracted dietary patterns. The first dietary pattern (eigenvalue 7.24) was named vegetable pattern because it had high factor loadings for vegetables. The second principal component (eigenvalue 2.59) was named high-fat pattern because of the high loadings for ham, mayonnaise, and deep fried foods. The third pattern (eigenvalue 2.21) had positive factor loadings for squid, shellfish, and cod roe – thus called seafood pattern. The fourth pattern (eigenvalue 1.99) was named bread and dairy pattern because of the high loadings for bread, butter, milk, and yogurt, and negative loading for rice. The fifth pattern (eigenvalue 1.65) had high loadings for milk, egg, tofu, and natto (fermented soybeans); we identified this as protein pattern.

Table 2 shows the associations between extracted dietary patterns and serum adiponectin in men and women by using multiple regression analyses. The result showed that bread and dairy pattern scores had positive significant association with serum adiponectin only in women (p = 0.004, 0.009, and 0.015 for model 1, 2, and 3, respectively). Addition of a product term between bread and dairy pattern score and menopausal status to model 2 and model 3 showed no evidence of significant interaction ($p = 0.41$ for model 2 and $p = 0.08$ for model 3, data not shown).

Table 3 shows the baseline characteristics of the study participants according to quartile of bread and dairy pattern score. Participants who had higher scores of bread and dairy pattern were more likely to be older, female, had lower energy intake, took part in more leisure time physical activity, and had higher concentrations of HDL cholesterol and serum adiponectin.

Figure 1 presents the path analysis model for women. This model showed good fit model to the data, with $\chi^2 = 18.634$, d.f. = 12, $p = 0.098$, standardized root mean square residual (SRMR) = 0.019, comparative fit index (CFI) = 0.992, and root mean square error of approximation (RMSEA) = 0.036. Significant association could be found between bread and dairy pattern and adiponectin ($p = 0.017$). Hereinafter, a negative association was seen between adiponectin and HOMA-IR ($p = 0.004$). Further, BMI was significantly inversely related to adiponectin and significantly positively influenced the HOMA-IR. The pathways of the path analysis model for Figure 1 is shown in Table 4.

The analyses of calcium, vitamin D, and potassium and their associations with adiponectin separately are shown in Supplementary Table 1. Significant association could only be found between potassium and adiponectin in women ($p = 0.019$, 0.004, and 0.039 for model 1, 2, and 3, respectively).

We found positive significant associations of bread and dairy pattern with adiponectin when waist circumference was used instead of BMI in model 3 (Supplementary Table 2) ($p = 0.030$).

In the supplementary figure 2, waist circumference was used instead of BMI for the path analysis. The model showed a good fit, with $\chi^2 = 20.511$, d.f. = 12, $p = 0.058$, SRMR = 0.020, CFI = 0.989, and RMSEA = 0.040. Similar to the result in figure 1, bread and dairy pattern was positively significantly associated with adiponectin (p = 0.028), followed with inverse significant association between adiponectin and HOMA-IR (p <0.001). Menopausal status was found to be positively significantly related to waist circumference. Furthermore, waist circumference was inversely significantly associated with adiponectin and positively related to HOMA-IR.Supplementary table 3 shows the pathways of path analysis model for suppelementary figure 2.

Discussion

In our study, derived dietary patterns were comparable to those of other studies in Japanese populations. For instance, the Japan Public Health Center-based Prospective Study (Nanri et al. 2013) extracted prudent, westernized, and traditional dietary patterns from its population. In another Japanese population, Nanri et al. (Nanri et al. 2008) obtained the healthy, high-fat, seafood, and westernized breakfast dietary pattern – with bread, margarine, and yogurt as part of its components.

Our study showed that dietary pattern characterized by high intake of bread and dairy products such as milk, butter, and yogurt, and low intake of rice was significantly related to a higher concentration of serum adiponectin, which is associated with the lower value of HOMA-IR in women. From our analysis, we infer that bread and dairy intake is one of the determinants of serum adiponectin, which has beneficial effects on the improvement of insulin resistance. Our result is in line with earlier systematic review study which revealed that higher intake of dairy products may have a positive effect on insulin sensitivity (Turner et al. 2015). However, in our study population, the indirect effect of the bread and dairy pattern score on HOMA-IR was considered to be rather small, as suggested by the product of the two standardized estimates (0.11 $\times$ [-0.13]).

The positive association between dairy products and serum adiponectin may be because of its contents, namely milk fat, vitamin D, calcium, potassium, whey protein, magnesium, or a combination of these components. Previous study showed that serum 25(OH)D was positively related to serum adiponectin (Vaidya et al. 2012). Meanwhile, dietary calcium may take part in the regulation of oxidative and inflammatory stress (Zemel & Sun 2008)– which negatively correlated with adiponectin (Furukawa et al. 2004). Increased magnesium intake may also have a favourable effect on adiponectin (Cassidy et al. 2009). Nonetheless, when we analysed the intake of calcium, vitamin D, and potassium and their associations with adiponectin separately, we could find significant association between only potassium and adiponectin (Supplementary Table 1). We consider that it is not calcium, vitamin D, or potassium per se that may increase the concentration of serum adiponectin, but the combination of those nutrients with other components within dairy products. In addition, when we analysed the correlation between main food items in bread and dairy pattern and adiponectin – only bread and butter were positively significantly correlated with adiponectin. As for the macronutrients intake, we did not find any significant correlation (data not shown). Possibly, the effect of single food items or nutrients were too small to be detected – compared to when they were measured together as a dietary pattern. In addition, the intercorrelation among individual food items and nutrients makes it hard to analyse their effect separately (Hu 2002).

Different from our results, one study stated that only low-fat dairy products were associated with increased serum adiponectin in a Japanese population (Niu et al. 2013). In our FFQ, we did not separate low- and high-fat dairy products. Nevertheless, the validation study of our FFQ using diet record showed that the proportion of low-fat dairy products in this population was low (data not shown). Further studies may be needed to clarify whether only low-fat dairy products are associated with high serum levels of adiponectin.

In the bread and dairy pattern, the factor loading of rice was negative. This may be because people consume bread as the staple food instead of rice. Separate analysis between rice intake and adiponectin showed that there was an inverse significant association between rice intake and adiponectin. Therefore, low intake of rice may in part contribute to the positive association between bread and dairy pattern and adiponectin. The possible reason for this is that rice, in general, has high glycaemic index/load and raise the blood glucose level (Foster-Powell et al. 2002). It has been suggested that glycaemic index and glycaemic load are inversely associated with adiponectin (Qi et al. 2006).

The result of multiple regression analysis for the association between bread and dairy pattern score and serum adiponectin in women (Table 2) showed that there was no substantial difference in the results between model 2 (not adjusted for BMI) and model 3 (additionally adjusted for BMI). Therefore, it is considered that BMI might not be the main underlying pathway in the positive association between bread and dairy pattern and serum adiponectin. This finding was concordant with the result of path analysis (Figure 1), which showed no significant association between bread and dairy pattern and BMI in this study population.

We speculated that insignificant association between bread and dairy pattern and adiponectin in men was possibly due to a small number of men in our study. Another possible reason is that consumption of bread and dairy products was below the amount required to have impact on adiponectin. Further, testosterone may suppress the production of adiponectin in men (Swarbrick & Havel 2008).

Several studies have reported the positive significant association between dietary patterns and serum adiponectin. Higher adherence to Mediterranean diet was significantly associated with increasing concentrations of serum adiponectin in the U.S. (Mantzoros et al. 2006). Another study in the U.S. (Fargnoli et al. 2008) indicated that higher Alternate Healthy Eating Index (AHEI) score (which reflects a healthier dietary pattern) was associated with higher HMW adiponectin concentrations. Meanwhile, investigation in a healthy Mediterranean women population revealed the positive effects of high non-refined cereals and low-fat dairy consumption on adiponectin (Yannakoulia et al. 2008). Compared to those studies, there was no common food content between those dietary patterns and our dietary pattern, except for low-fat dairy products. One reason for the difference may be that average food and nutritional intake greatly differ among the countries or population studied.

This study has several limitations. First, the relationship between bread and dairy pattern and serum adiponectin should be interpreted with caution in term of time sequence, because cross-sectional study design was used. Second, we had no data on the validity of dietary pattern. However, other studies showed that validity and reproducibility of the dietary pattern assessed from FFQ were acceptable (Hu et al. 1999; Nanri et al. 2012). Third, information on dietary intake and lifestyle factors were collected using self-reported questionnaire. Thus, random measurement error might be inevitable. Fourth, in the FFQ, we did not further classify the type of bread (refined or whole grain) and dairy products (low-fat or high-fat). Nevertheless, our dietary records showed that majority of our study participants consumed refined bread and normal dairy products. Fifth, dietary patterns might depend on the statistical method used and interpretation might be subjective, and it is uncertain if the results are applicable to other populations. Nonetheless, our dietary patterns were similar to those reported for another study in a Japanese population (Nanri et al. 2008). Lastly, the subjects in our study were Japanese, thus, our result may not be generalizable to other ethnic populations.

In conclusion, the result of the present study show that dietary pattern characterized by high consumption of bread and dairy products, and low intake of rice was positively but weakly related to higher concentration of serum adiponectin in women. Further studies are needed to clarify the biological mechanisms for the beneficial effects of dairy products toward serum adiponectin.

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Disclosure statement

The authors declare that there is no conflict of interest.

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References

Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, Fruchart J-C, James WPT, Loria CM, Smith SC. 2009. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International. Circulation [Internet]. [cited 2014 Jul 9]; 120:1640–5. Available from: http://circ.ahajournals.org/content/120/16/1640.full#cited-by

Antuna-Puente B, Disse E, Rabasa-Lhoret R, Laville M, Capeau J, Bastard J-P. 2011. How can we measure insulin sensitivity/resistance? Diabetes Metab [Internet]. [cited

2014 Jul 28]; 37:179–88. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21435930

Balkau B, Charles MA. 1999. Comment on the provisional report from the WHO consultation. European Group for the Study of Insulin Resistance (EGIR). Diabet Med [Internet]. [cited 2014 Sep 13]; 16:442–3. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10342346

Barrett P. 2007. Structural equation modelling: Adjudging model fit. Pers Individ Dif [Internet]. [cited 2014 Jul 16]; 42:815–824. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0191886906003837

Cameron AJ, Shaw JE, Zimmet PZ. 2004. The metabolic syndrome: prevalence in worldwide populations. Endocrinol Metab Clin North Am [Internet]. [cited 2014 Sep 29]; 33:351–75. Available from: http://www.sciencedirect.com/science/article/pii/S0889852904000222

Cassidy A, Skidmore P, Rimm EB, Welch A, Fairweather-Tait S, Skinner J, Burling K, Richards JB, Spector TD, MacGregor AJ. 2009. Plasma adiponectin concentrations are associated with body composition and plant-based dietary factors in female twins. J Nutr [Internet]. [cited 2016 Apr 4]; 139:353–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19106327

Choi J-H, Yu M, Kim K-E. 2014. Suicidal ideation in adolescents: A structural equation modeling approach. Nurs Health Sci [Internet]. [cited 2014 Jul 31]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24943997

Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood

Cholesterol In Adults (Adult Treatment Panel III). 2001. JAMA [Internet]. [cited 2014 Jul 13]; 285:2486–97. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11368702

Fargnoli JL, Fung TT, Olenczuk DM, Chamberland JP, Hu FB, Mantzoros CS. 2008. Adherence to healthy eating patterns is associated with higher circulating total and high-molecular-weight adiponectin and lower resistin concentrations in women from the Nurses' Health Study. Am J Clin Nutr. 88:1213–1224.

Foster-Powell K, Holt SHA, Brand-Miller JC. 2002. International table of glycemic index and glycemic load values: 2002. Am J Clin Nutr [Internet]. [cited 2017 Jan 31]; 76:5–56. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12081815

Furukawa S, Fujita T, Shimabukuro M, Iwaki M, Yamada Y, Nakajima Y, Nakayama O, Makishima M, Matsuda M, Shimomura I. 2004. Increased oxidative stress in obesity and its impact on metabolic syndrome. J Clin Invest [Internet]. [cited 2015 Mar 3]; 114:1752–61. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=535065&tool=pmcentrez&rendertype=abstract

Goto C, Tokudome Y, Imaeda N, Takekuma K, Kuriki K, Igarashi F, Ikeda M, Tokudome S. 2006. Validation study of fatty acid consumption assessed with a short food frequency questionnaire against plasma concentration in middle-aged Japanese people. Scand J Food Nutr. 50:77–82.

Grundy SM, Brewer HB, Cleeman JI, Smith SC, Lenfant C. 2004. Definition of metabolic syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. In: Circulation [Internet]. Vol. 109. [place unknown]; [cited 2014 Jul 10]; p. 433–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/14744958

Guo H, Niu K, Monma H, Kobayashi Y, Guan L, Sato M, Minamishima D, Nagatomi R. 2012. Association of Japanese dietary pattern with serum adiponectin concentration in Japanese adult men. Nutr Metab Cardiovasc Dis [Internet]. [cited 2015 Feb 2]; 22:277–84. Available from: http://www.sciencedirect.com/science/article/pii/S0939475310001390

Hamajima N. 2007. The Japan Multi-Institutional Collaborative Cohort Study (J-MICC Study) to detect gene-environment interactions for cancer. Asian Pac J Cancer Prev [Internet]. [cited 2014 Jul 31]; 8:317–23. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17696755

Hara K, Horikoshi M, Yamauchi T, Yago H, Miyazaki O, Ebinuma H, Imai Y, Nagai R, Kadowaki T. 2006. Measurement of the high-molecular weight form of adiponectin in plasma is useful for the prediction of insulin resistance and metabolic syndrome. Diabetes Care [Internet]. [cited 2014 Jul 31]; 29:1357–62. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16732021

Hu FB. 2002. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol [Internet]. [cited 2017 Apr 18]; 13:3–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11790957

Hu FB, Rimm E, Smith-Warner SA, Feskanich D, Stampfer MJ, Ascherio A, Sampson L, Willett WC. 1999. Reproducibility and validity of dietary patterns assessed with a food- frequency questionnaire. Am J Clin Nutr [Internet]. [cited 2017 Jan 26]; 69:243–249. Available from: http://www.ncbi.nlm.nih.gov/pubmed/9989687

Hu L, Bentler PM. 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Model A Multidiscip J [Internet]. [cited 2014 Jul 9]; 6:1–55. Available from:

http://dx.doi.org/10.1080/10705519909540118

Imaeda N, Goto C, Tokudome Y, Hirose K, Tajima K, Tokudome S. 2007. Reproducibility of a short food frequency questionnaire for Japanese general population. J Epidemiol. 17:100–107.

Kline RB. 2011. Principles and practice of structural equation modeling. 3rd ed. New York: The Guilford Press.

Lindsay RS, Funahashi T, Hanson RL, Matsuzawa Y, Tanaka S, Tataranni PA, Knowler WC, Krakoff J. 2002. Adiponectin and development of type 2 diabetes in the Pima Indian population. Lancet [Internet]. 360:57–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12114044

Mantzoros CS, Williams CJ, Manson JE, Meigs JB, Hu FB. 2006. Adherence to the Mediterranean dietary pattern is positively associated with plasma adiponectin concentrations in diabetic women. Am J Clin Nutr. 84:328–335.

Matthews DR, Hosker JR, Rudenski AS, Naylor BA, Treacher DF, Turner RC, Infirmary R. 1985. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 28:412–419.

Mittal S. 2008. The Metabolic Syndrome in Clinical Practice. London: Springer-Verlag.

Murakami K, Sasaki S, Uenishi K. 2013. Serum adiponectin concentration in relation to macronutrient and food intake in young Japanese women. Nutrition [Internet]. [cited 2015 Feb 3]; 29:1315–20. Available from: http://www.sciencedirect.com/science/article/pii/S0899900713002256

Nanri A, Mizoue T, Yoshida D, Takahashi R, Takayanagi R. 2008. Dietary patterns and

A1C in Japanese men and women. Diabetes Care [Internet]. [cited 2016 Mar 11]; 31:1568–73. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2494650&tool=pmcentrez&rendertype=abstract

Nanri A, Shimazu T, Ishihara J, Takachi R, Mizoue T, Inoue M, Tsugane S, JPHC FFQ Validation Study Group. 2012. Reproducibility and validity of dietary patterns assessed by a food frequency questionnaire used in the 5-year follow-up survey of the Japan Public Health Center-Based Prospective Study. J Epidemiol [Internet]. [cited 2017 Jan 26]; 22:205–15. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22343330

Nanri A, Shimazu T, Takachi R, Ishihara J, Mizoue T, Noda M, Inoue M, Tsugane S. 2013. Dietary patterns and type 2 diabetes in Japanese men and women: the Japan Public Health Center-based Prospective Study. Eur J Clin Nutr [Internet]. [cited 2015 Sep 1]; 67:18–24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23093343

Niu K, Kobayashi Y, Guan L, Monma H, Guo H, Cui Y, Otomo A, Chujo M, Nagatomi R. 2013. Low-fat dairy, but not whole-/high-fat dairy, consumption is related with higher serum adiponectin levels in apparently healthy adults. Eur J Nutr [Internet]. [cited 2014 Jul 31]; 52:771–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22648202

Pajvani UB, Du X, Combs TP, Berg AH, Rajala MW, Schulthess T, Engel J, Brownlee M, Scherer PE. 2003. Structure-function studies of the adipocyte-secreted hormone Acrp30/adiponectin. Implications fpr metabolic regulation and bioactivity. J Biol Chem [Internet]. [cited 2016 May 16]; 278:9073–85. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12496257

Pischon T, Girman CJ, Hotamisligil GS, Rifai N, Hu FB, Rimm EB. 2004. Plasma adiponectin levels and risk of myocardial infarction in men. JAMA [Internet]. [cited 2016 Apr 11]; 291:1730–7. Available from: http://jama.jamanetwork.com/article.aspx?articleid=198539

Porta M, editor. 2008. A Dictionary of Epidemiology. 5th ed. New York: Oxford University Press.

Qi L, Meigs JB, Liu S, Manson JE, Mantzoros C, Hu FB. 2006. Dietary fibers and glycemic load, obesity, and plasma adiponectin levels in women with type 2 diabetes. Diabetes Care [Internet]. [cited 2016 Apr 5]; 29:1501–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16801569

Swarbrick MM, Havel PJ. 2008. Physiological, pharmacological, and nutritional regulation of circulating adiponectin concentrations in humans. Metab Syndr Relat Disord [Internet]. [cited 2017 Jan 19]; 6:87–102. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18510434

Tokudome S, Goto C, Imaeda N, Tokudome Y, Ikeda M, Maki S. 2004. Development of a data-based short food frequency questionnaire for assessing nutrient intake by middle-aged Japanese. Asian Pac J Cancer Prev [Internet]. [cited 2014 Sep 17]; 5:40–3. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15075003

Tokudome Y, Goto C, Imaeda N, Hasegawa T, Kato R, Hirose K, Tajima K, Tokudome S. 2005. Relative validity of a short food frequency questionnaire for assessing nutrient intake versus three-day weighed diet records in middle-aged Japanese. J Epidemiol [Internet]. [cited 2016 Feb 12]; 15:135–45. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16141632

Turner KM, Keogh JB, Clifton PM. 2015. Dairy consumption and insulin sensitivity: a systematic review of short- and long-term intervention studies. Nutr Metab Cardiovasc Dis [Internet]. [cited 2016 Mar 30]; 25:3–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25156891

Vaidya A, Williams JS, Forman JP. 2012. The independent association between 25-hydroxyvitamin D and adiponectin and its relation with BMI in two large cohorts: the NHS and the HPFS. Obesity (Silver Spring) [Internet]. [cited 2016 Mar 31]; 20:186–91. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3461263&tool=pmcentrez&rendertype=abstract

Waki H, Yamauchi T, Kamon J, Ito Y, Uchida S, Kita S, Hara K, Hada Y, Vasseur F, Froguel P, et al. 2003. Impaired multimerization of human adiponectin mutants associated with diabetes. Molecular structure and multimer formation of adiponectin. J Biol Chem [Internet]. [cited 2014 Jul 16]; 278:40352–63. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12878598

Xu A, Wang Y, Lam KSL. 2007. Adiponectin. In: Fantuzzi G, Mazzone T, editors. Adipose Tissue Adipokines Heal Dis. New Jersey: Humana Press; p. 47.

Yannakoulia M, Yiannakouris N, Melistas L, Kontogianni MD, Malagaris I, Mantzoros CS. 2008. A dietary pattern characterized by high consumption of whole-grain cereals and low-fat dairy products and low consumption of refined cereals is positively associated with plasma adiponectin levels in healthy women. Metabolism. 57:824–830.

Zemel MB, Sun X. 2008. Dietary calcium and dairy products modulate oxidative and inflammatory stress in mice and humans. J Nutr [Internet]. 138:1047–52. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18492832

Table 1. Factor loading matrix for the extracted dietary patterns

Table 2. Associations between extracted dietary patterns and serum adiponectin in men and women

Table 3. Baseline characteristics of the study participants based on the quartiles of the bread and dairy pattern intake

Table 4. Pathways of the path model

Figure 1. Path diagram of the association between bread and dairy pattern, serum adiponectin, and insulin resistance in women. *$p<0.05$ **$p<0.01$ ***$p<0.001$; solid lines represent significant relationships; dashed lines represent non-significant relationships; drinking habit: does not have a drinking habit = 0, has a drinking habit = 1; smoking habit: does not have a smoking habit = 0, has a smoking habit = 1; menopausal status: woman with pre-menopausal status = 0, woman with post-menopausal status = 1; BMI = Body Mass Index, HOMA-IR = Homeostasis Model Assessment Insulin Resistance.

Table 1. Factor loading matrix for the extracted dietary patterns

Food items	Vegetable pattern	High-fat pattern	Seafood pattern	Bread and dairy pattern	Protein pattern
Rice	-	-0.20	0.26	-0.51	-
Bread	-	0.25	-0.25	0.55	-
Noodle	-	0.37	-	-	-
Bread & margarine	-	0.31	-0.17	0.25	-
Bread & butter	-	-	-	0.35	-
Milk	-	-	-	0.36	0.38
Yogurt	0.30	-	-	0.44	-
Miso	0.41	-	0.16	-	-
Chilled tofu & toppings, boiled tofu	0.41	-	0.27	-	0.28
Natto (fermented soybeans), soya beans (other cooked beans)	0.45	-0.20	0.23	0.16	0.33
Egg	0.30	0.21	-	-	0.36
Chicken	0.21	0.32	-	-0.31	0.24
Beef, pork	0.22	0.34	-0.15	-0.25	-
Liver	-	-	0.24	0.17	-
Ham, sausage, salami, bacon	0.20	0.44	-	-	0.16
Fish (such as sashimi, boiled fish, grilled fish)	0.40	-0.16	0.34	-	-
Small fish eaten with its bone	0.46	-0.21	0.23	0.20	-
Canned tuna	0.16	0.18	0.14	0.22	-
Squid, shrimp, crab, octopus	0.34	0.34	0.34	-	-0.30
Shellfish (such as clam, oyster)	0.33	0.27	0.46	0.15	-0.26
Cod roe, salmon roe	0.20	0.20	0.51	-	-
Fish paste cake, steamed seasoned fish paste	0.42	0.20	0.22	-	-
Deep-fried tofu with thinly sliced vegetables, deep-fried bean curd, deep fried tofu	0.50	-	0.18	-	-
Potato, taro, sweet potato	0.61	-	-	-	-
Pumpkin	0.56	-	-	-	0.19
Carrot	0.57	-	-0.19	-0.18	0.28
Broccoli	0.48	-	-	-	0.19
Green leafy vegetables (such as spinach, Japanese mustard spinach, edible chrysanthemum)	0.57	-0.25	-	-0.20	-
Green & yellow vegetables (such as green pepper, green beans)	0.57	-0.25	-	-0.17	-
Cabbage	0.56	-	-	-	-
Radish (boiled & grated radish)	0.60	-	-	-	-
Dried radish	0.46	-	0.29	0.16	-
Burdock, bamboo shoot	0.49	-	-	-	-
Other light-colored vegetables (such as cucumber, onion, bean sprouts, Chinese cabbage, lettuce)	0.61	-	-0.26	-0.26	-
Mushroom (shiitake, enoki, shimeji)	0.61	-	-0.25	-0.15	-
Seaweed (such as hijiki, kelp)	0.59	-0.19	-	-	-0.24
Mayonnaise (including potato salad)	0.17	0.58	-	-	-
Deep-fried food	0.20	0.60	-	-0.28	-0.15
Stir fry food (dish made with small amount of oil)	0.37	0.35	-0.23	-0.28	-
Mandarin orange, orange, grapefruit	0.48	-0.16	-0.19	0.20	-0.29
Other fruits (strawberry, kiwi, apple, watermelon)	0.49	-0.26	-0.28	0.23	-0.21
Peanuts, almond	0.36	-	-0.38	-	-0.23
Western confectionary (such as cake, creampuff)	0.29	0.26	-0.39	-	-0.41
Japanese confectionary (such as steamed bun)	0.46	0.20	-0.20	-	-0.30
Green tea	0.24	-	0.21	-	-0.32
Coffee	-	0.26	-0.27	0.17	-
Eigenvalue	7.24	2.59	2.21	1.99	1.65
Cumulative variance explained (%)	15.7	21.4	26.2	30.5	34.1

Factor loadings are equivalent to Pearson correlation between the food items and the dietary patterns.
For simplicity, factor loadings less than ±0.15 were indicated by dash.

Table 2. Associations between extracted dietary patterns and serum adiponectin in men and women participants

Dietary pattern			Parameter estimate	Standard error	$R^{2\dagger}$	*p*
Vegetable pattern	Men	Model 1	-0.011	0.008	0.012	0.191
		Model 2	-0.009	0.009	0.108	0.308
		Model 3	-0.011	0.009	0.167	0.219
	Women	Model 1	0.003	0.005	0.016	0.526
		Model 2	0.004	0.005	0.032	0.484
		Model 3	0.0003	0.005	0.155	0.948
High-fat pattern	Men	Model 1	-0.007	0.013	0.003	0.589
		Model 2	-0.0001	0.013	0.102	0.991
		Model 3	-0.003	0.013	0.160	0.842
	Women	Model 1	-0.002	0.007	0.015	0.774
		Model 2	-0.004	0.008	0.032	0.626
		Model 3	0.004	0.007	0.156	0.611
Seafood pattern	Men	Model 1	-0.017	0.016	0.008	0.293
		Model 2	-0.014	0.016	0.106	0.382
		Model 3	-0.011	0.016	0.162	0.504
	Women	Model 1	-0.009	0.007	0.018	0.251
		Model 2	-0.011	0.008	0.036	0.155
		Model 3	-0.008	0.007	0.158	0.243
Bread and dairy pattern	Men	Model 1	0.007	0.015	0.003	0.627
		Model 2	0.008	0.015	0.104	0.575
		Model 3	0.006	0.014	0.161	0.667
	Women	Model 1	0.024	0.008	0.034	0.004
		Model 2	0.022	0.008	0.047	0.009
		Model 3	0.019	0.008	0.167	0.015
Protein pattern	Men	Model 1	0.002	0.019	0.002	0.922
		Model 2	0.002	0.018	0.102	0.932
		Model 3	-0.001	0.018	0.160	0.949
	Women	Model 1	0.003	0.009	0.015	0.734
		Model 2	0.005	0.009	0.032	0.541
		Model 3	-0.002	0.008	0.155	0.786

Model 1: Adjusted for age

Model 2: Adjusted for age, energy intake, physical activity, drinking habit, smoking habit, and menopausal status (women only)

Model 3: Adjusted for age, energy intake, physical activity, drinking habit, smoking habit, menopausal status (women only), and BMI

$^{\dagger}R^2$ of the model including dietary pattern and all covariates

Table 3. Baseline characteristics of the study participants based on the quartiles of the bread and dairy pattern intake

	Quartiles of bread and dairy pattern intake				*p*
	Q1	Q2	Q3	Q4	
Age (years)†	50 (41, 60)	50 (41, 61)	53 (44, 61)	59 (50, 64)	<0.0001
Sex‡					
Male	52 (34.0)	51 (33.3)	34 (22.2)	38 (24.8)	0.047
Female	101 (66.0)	102 (66.7)	119 (77.8)	115 (75.2)	
BMI (kg/m^2)†	23.0 (20.6, 26.0)	22.3 (20.1, 24.4)	22.5 (20.0, 24.4)	22.5 (20.5, 24.4)	0.123
Waist circumference (cm)†	81.0 (74.0, 90.0)	79.5 (73.0, 87.0)	80.0 (73.5, 85.0)	79.0 (73.5, 86.0)	0.259
Smoking‡					
Current	18 (11.8)	20 (13.1)	14 (9.2)	16 (10.5)	
Past	36 (23.5)	27 (17.7)	25 (16.3)	25 (16.3)	0.497
Never	99 (64.7)	106 (69.3)	114 (74.5)	112 (73.2)	
Drinking‡					
Current	65 (42.5)	77 (50.3)	70 (45.8)	70 (45.8)	
Past	2 (1.3)	3 (2.0)	2 (1.3)	2 (1.3)	0.863
Never	86 (56.2)	73 (47.7)	81 (52.9)	81 (52.9)	
Total energy intake (kcal/day)†	1659 (1492, 1885)	1542 (1375, 1720)	1533 (1335, 1690)	1562 (1396, 1733)	<0.0001
Physical activity (MET-hours/week)†	5.1 (0.4, 16.8)	3.8 (0.4, 15.3)	5.1 (0.4, 17.9)	9.2 (1.3, 28.5)	0.002
Triglycerides (mg/dl)†	87 (60, 128)	80 (56, 116)	77 (58, 103)	72 (56, 109)	0.159
HDL cholesterol (mg/dl)†	57 (48, 68)	59 (51, 71)	61 (55, 70)	63 (50, 71)	0.043
Fasting plasma glucose (mg/dl)†	89 (84, 93)	89 (85, 95)	89 (85, 94)	90 (85, 96)	0.529
Insulin (µU/ml)†	4.7 (3.4, 6.8)	4.5 (2.9, 6.3)	4.3 (3.2, 6.2)	4.3 (3.0, 5.7)	0.323
HOMA-IR†	1.04 (0.76, 1.54)	1.01 (0.63, 1.43)	0.95 (0.69, 1.41)	0.94 (0.64, 1.34)	0.446
Serum Adiponectin (µg/mL)†	3.68 (2.42, 6.12)	4.28 (2.45, 6.70)	4.88 (3.29, 6.76)	4.78 (3.24, 7.38)	0.004

†Median (25%; 75%), ‡Number (%)

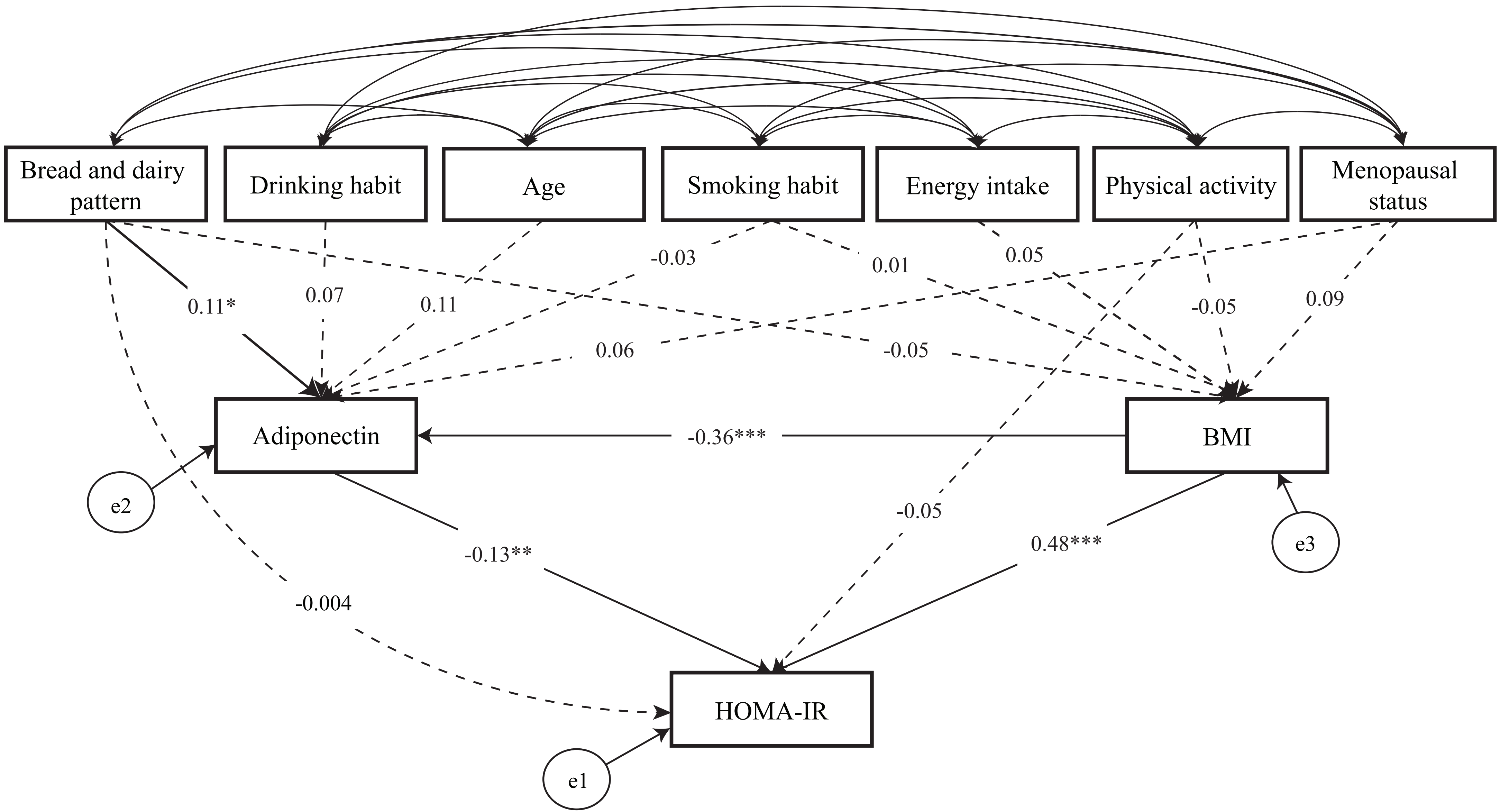
BMI = Body Mass Index; MET = metabolic equivalent; HOMA-IR = Homeostasis Model Assessment Insulin Resistance

Table 4. Pathways of the path model

	Standardized estimate	Unstandardized estimate	Standard error	*p*
BMI ← bread and dairy pattern score	-0.045	-0.002	0.002	0.357
BMI ← energy intake	0.054	0.048	0.043	0.267
BMI ← physical activity	-0.049	-0.003	0.003	0.322
BMI ← smoking	0.012	0.003	0.011	0.798
BMI ← menopausal status	0.085	0.011	0.006	0.085
Adiponectin ← bread and dairy pattern score	0.107	0.018	0.008	0.017
Adiponectin ← drink	0.074	0.037	0.022	0.093
Adiponectin ← age	0.105	0.003	0.002	0.177
Adiponectin ← smoking	-0.026	-0.024	0.041	0.563
Adiponectin ← BMI	-0.36	-1.405	0.171	<0.001
Adiponectin ← menopause	0.062	0.031	0.038	0.418
HOMA-IR ← adiponectin	-0.126	-0.131	0.045	0.004
HOMA-IR ← BMI	0.478	1.93	0.174	<0.001
HOMA-IR ← physical activity	-0.047	-0.013	0.011	0.251
HOMA-IR ← bread and dairy pattern score	-0.004	-0.001	0.007	0.926

BMI = Body Mass Index; HOMA-IR = Homeostasis Model Assessment Insulin Resistance

Figure 1.



Bread and dairy pattern
Drinking habit
Age
Smoking habit
Energy intake
Physical activity
Menopausal status
0.11*
0.07
0.11
-0.03
0.01
0.05
-0.05
0.09
0.06
-0.05
Adiponectin
-0.36***
BMI
e2
e3
-0.05
-0.13**
0.48***
-0.004
HOMA-IR
e1